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Title: Effect of Hydrogen Peroxide Treatment on Microbial Quality and Appearance of Whole and Fresh-Cut Melons Contaminated with *Salmonella Spp.*

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Effect of hydrogen peroxide treatment on microbial quality and appearance of whole and fresh-cut melons contaminated with *Salmonella* spp.[☆]

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Abstract

The efficacy of hydrogen peroxide treatment on the inactivation of *Salmonella* spp. inoculated on the external surface of cantaloupe and honeydew melon was investigated. *Salmonella* was inoculated onto whole cantaloupe and honeydew melon to a final concentration of 4.65 log₁₀ CFU/cm² and 3.13 log₁₀ CFU/g, respectively. Inoculated whole melons stored at 5 °C for up to 7 days were washed with water, 2.5% and 5% hydrogen peroxide at day 0 and 5. Hydrogen peroxide (2.5% and 5%) treatments of whole melon for 5 min caused a 3 log₁₀ CFU/cm² reduction of the indigenous surface microflora and a 3.0 log₁₀ CFU/cm² reduction in *Salmonella* spp. on all melon surfaces. The efficacy of the hydrogen peroxide treatments was less when the interval between inoculation and treatment of cantaloupe exceeded 24 h. Unlike cantaloupe fresh-cut pieces, *Salmonella* was not recovered from fresh-cut pieces prepared from treated whole honeydew melon. Growth of *Salmonella* occurred in cantaloupe fresh-cut pieces stored at 10 or 20 °C, and by 2 weeks, levels reached approximately 1 log CFU/g. A rapid decline in appearance and overall acceptability was observed in fresh-cut pieces prepared from untreated whole cantaloupe. While *Salmonella* was recovered from fresh-cut pieces from and whole treated cantaloupe, sanitizing the surface of contaminated whole melons with hydrogen peroxide before and after cutting and storage of the fresh-cut pieces at 5 °C can enhance the microbial safety and acceptability rating for about 2 weeks after processing.

Keywords: Cantaloupe; Honeydew; Fresh-cut pieces; *Salmonella*; Hydrogen peroxide

1. Introduction

Fruits and vegetables are frequently in contact with soil, insects, animals, or humans during growing or

harvesting (Shewfelt, 1987) and in the processing plant. Thus, their surfaces are exposed to natural contaminants, and by the time they reach the packinghouse, most fresh produce retain populations of 10⁴–10⁶ microorganisms/g (Beuchat, 1995; Brackett 1992). Cantaloupes and other melons have been associated with numerous outbreaks of food-borne illness in recent years (CDC, 2002; Dewaal et al., 2000; Gayler et al., 1955; Ries et al., 1990). The causative organisms in several cantaloupe-related outbreaks were

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Salmonella spp. including Chester and Poona (Ries et al., 1990; FDA, 2000; CDC, 2002). Contamination most likely originates directly or indirectly from fecal matter either pre- or postharvest and may involve use of contaminated irrigation water or uncomposted manure. Contributing factors include poor hygiene and unsanitary procedures of field and processing workers, inadequate cleaning of processing equipment, the use of decayed or damaged melons and failure to wash melon properly before fresh-cut processing (Beuchat, 1995; Brackett, 1992; NACMCF, 1999; Nguyen-The and Carlin, 1994). The recent FDA survey of imported fresh produce reported an incidence of 5.3% positives for *Salmonella* and 2% for *Shigella* in 151 samples of cantaloupes, all contaminated melons originating in Mexico, Costa Rica and Guatemala (FDA, 2001a). In a survey of domestic fresh produce (FDA, 2001b), 2.6% were positive for *Salmonella*, and 0.9% were positive for *Shigella* in 115 samples of cantaloupes.

Minimally processed fruits and vegetables are more perishable than the intact products from which they were prepared (Watada et al., 1990). These products have a limited shelf life due to deterioration caused by microbial spoilage as well as physiological deterioration. Cutting of fruits may increase microbial spoilage of fruits through transfer of microflora on the outer surfaces to the interior tissue where microorganisms have access to nutrient-laden juice (O'Connor-Shaw et al., 1994; Marston, 1995; Nguyen-The and Carlin, 1994). The nutrients may also allow the proliferation of human pathogenic organisms including *Salmonella* spp. and *Escherichia coli* O157:H7 when proper sanitation and strict temperature control is not maintained (Golden et al., 1993; Del Rosario and Beuchat, 1995; O'Connor-Shaw et al., 1994; Ukuku and Sapers, 2001). Salmonellosis has been steadily increasing as a public health problem in the United States since reporting began in 1943 (Tamplin, 1997). Six outbreaks of salmonellosis in the US have been associated epidemiologically with cantaloupe since 1990. The first involved *S. Chester* which affected 245 individuals (two deaths) in 30 states (Ries et al., 1990). A second outbreak in 1991 involved more than 400 laboratory confirmed cases of *S. Poona* infections in 23 states and Canada (CDC, 1991).

Chlorination of wash water up to 200 ppm is routinely applied to reduce microbial contamination in produce processing lines (Wei et al., 1985). How-

ever, the use of chlorine is of concern due to the potential formation of harmful by-products (Richardson et al., 1998) and can only achieve approximately 2–3 log reductions of native microflora (Ukuku et al., 2001). Thus, there is much interest in developing safer and more effective sanitizers. We have investigated the use of a hydrogen peroxide wash for reducing the native microflora on whole cantaloupe surfaces (Ukuku et al., 2001) and minimally processed fruits and vegetables (Sapers et al., 2001). In this study, the efficacy of hydrogen peroxide treatments in reducing *Salmonella* on whole and fresh-cut melons, and its impact on the appearance and overall acceptability of fresh-cut pieces, during storage at 5, 10, or 20 °C for up to 15 days was investigated.

2. Materials and methods

2.1. Bacterial strains, growth conditions and preparation

Bacterial strains used in this study were *Salmonella* Stanley H0558, *Salmonella* Newport H1275, *Salmonella* Anatum F4317, *Salmonella* Infantis F4319 (all associated with alfalfa sprout-related outbreaks) and *Salmonella* Poona RM2350 (associated with a cantaloupe-related outbreak) (obtained from Ms. Sharon Abbott and Dr. Michael Jordan, California Dept. of Health Services). Bacteria were maintained on Brain Heart Infusion Agar (BHIA, Difco, Detroit, MI) slants held at 4 °C. Prior to use, the cultures were subjected to two successive transfers by loop inocula to 5 ml Brain Heart Infusion Broth (BHIB, BBL/Difco). A final transfer of 0.2 ml was made into 20 ml BHIB with incubation at 36 °C for 18 h under static conditions. Bacterial cells were harvested by centrifugation (10,000g, 5 min) at 4 °C, and the cell pellets were washed in salt-peptone [0.85% NaCl, 0.05% Bacto-peptone (BBL/Difco)]. A cocktail of all five *Salmonella* inocula containing approximately 2×10^8 CFU/ml of each strain was prepared in 3 l of 0.1% (w/v) peptone–water.

2.2. Inoculation of cantaloupes

Cantaloupes (1621 ± 48 g) and honeydew (1781 ± 33 g) melons were purchased from a local

wholesale distribution center. Melons were stored at 4 °C. Before use, melons were unpacked and placed on the laboratory bench for ~18 h to allow them to come to room temperature (~20 °C). The melons were then completely submerged in 3 l of bacterial inoculum (~20 °C) and agitated by stirring with a glove-covered hand for 10 min to ensure an even inoculation. Inoculated melons were placed inside a biosafety cabinet to dry for 1 h and then stored at 20 °C for up to 3 days before sanitizer treatments were applied.

2.2.1. Preparation of wash solutions

Solutions of 0%, 2.5% and 5% H₂O₂ were prepared from a 30% stock solution (reagent grade, Fisher Scientific, Suwanee, GA) by dilution with sterilized tap water.

2.2.2. Washing treatments

Washing treatments were performed by submerging the melons in 3 l sterile tap water, or hydrogen peroxide (2.5 and 5%) and agitating for 5 min with a glove-covered hand to assure complete coverage with the wash solution. Washed melons were placed inside a biosafety cabinet to dry for 1 h before preparation of the fresh-cut pieces.

2.2.3. Preparation of fresh-cut pieces

All utensils and equipment used for preparing fresh-cut pieces were sanitized with 200 ppm chlorinated water. Treated and untreated inoculated whole melons were cut into four sections using a sterile knife, and the rinds were carefully removed. The interior flesh was cut into ~3-cm cubes, and pieces were washed for 1 min with either sterile tap water or 1% hydrogen peroxide before placing them (100 g) inside a Stomacher® bag (Dynatech Laboratories, Alexandria, VA). Bags containing the pieces were stored at 5, 10 and 20 °C for up to 15 days.

2.3. Microbiological analysis

Seventy melon rind plugs per whole melon were used for microbiological analysis. A sterilized stainless steel cork-borer was used to cut through the cantaloupe or honeydew whole melon surfaces at random locations to produce rind plugs of 22 mm in diameter with a rind surface area (πr^2) of 3.80 cm².

Flesh adhering to the rind plugs was trimmed off using a sterile stainless steel knife. Rind plugs (70 per cantaloupe) weighing approximately 20 g were blended (Waring commercial blender, Dynamic, New Hartford, CT, speed set at level 5) for 1 min with 80 ml of sterile 0.1% peptone water. Decimal dilutions of the sample were made with 0.1% peptone water, and aliquots (0.1 ml) were plated in duplicate on a range of media. Plate Count Agar (PCA, Difco/BBL Becton Dickinson Sparks, MD), with incubation at 30 °C for 3 days, was used for enumeration of mesophilic aerobes (Messer et al., 1984). *Salmonella* was enumerated on SS agar (Difco, MD) with incubation at 35 °C for 48 h. For comparison, a pure culture of *Salmonella* was plated on SS agar (Difco), incubated as above, and run parallel with the samples. Selected black or black-centered colonies from the agar plates were confirmed to be *Salmonella* following conventional biochemical methods (Andrews et al., 1995).

2.4. Microbiology of fresh-cut pieces

Bags containing the fresh-cut pieces stored at 5, 10 and 20 °C were monitored for the presence and growth of aerobic mesophilic bacteria and *Salmonella* every 3 days for up to 15 days. Two hundred milliliters of nutrient broth (Difco) or 0.1% peptone water was added to the fresh-cut pieces (100 g) inside a Stomacher® bag and pummeled for 30 s in a Stomacher model 400 (Dynatech Laboratories) at medium speed. Aliquots (0.1 ml) from the samples prepared in 0.1% peptone were plated in duplicate on the media described above. Samples were subjected to pre-enrichment by adding 200 ml nutrient broth to the samples prepared in 0.1% peptone with incubation at 35 °C for 18–22 h. For selective enrichment of *Salmonella*, a 1-ml aliquot of the pre-enriched sample was added to 9 ml of tetrathionate broth (BBL/Difco) and incubated at 35 °C for 24 h. Aliquots (0.1 ml) from the enrichments were plated on SS agar and incubated as stated above.

2.5. Quality evaluation

Panelist selection and training and quality evaluation were undertaken as described by O'Connor-Shaw et al. (1994), which was a slight modification of a procedure described by Kader et al. (1973). Treated

fresh-cut melon pieces were scored for appearance and overall acceptability using a predetermined list of descriptors (9=excellent, 8=very good, 7=good, 6=not good but fair, 5=fair, 4=bad, 3=poor, 2=very poor, 1=unusable) for appearance and (8=highly acceptable, 7=very good, 6=acceptable, 5=fair, 4=less acceptable, 3=poor, 2=very poor, 1=unacceptable) for overall acceptability. A panel of five judges was used to evaluate the quality of fresh-cut melons during refrigerated storage (5 °C) at days 0, 3, 6, 9, 12 and 15. On each day of testing, panelists were presented with freshly cut melon pieces as a reference.

2.5.1. Data analysis

All experiments were replicated three times. Data from each treatment were subjected to the Statistical Analysis System (SAS Institute, Cary, NC) for analysis of variance (ANOVA) and the Bonferroni LSD method (Miller, 1981) to determine significant differences between treatments and storage temperatures.

3. Results and discussion

3.1. Effect of treatments on native microflora of cantaloupe rind

Initial populations of native microflora on the rind of unwashed whole cantaloupes and honeydew melons are shown in Table 1. The rind of cantaloupe melon supported higher populations of microbes than the honeydew rind. The difference in the populations of the native microflora on the

honeydew and cantaloupe rind is most likely due to the rough surface of the cantaloupe rind compared to the relatively smooth surface of honeydew melon. The extensive raised netting on the surface of cantaloupe melon no doubt provides more microbial attachments sites and helps to protect attached microbes from being washed from the surface, and possibly from environmental stresses such as UV radiation and desiccation. Surface irregularities such as roughness, crevices and pits have been shown to increase bacterial adherence and reduce the ability of washing treatments to remove bacterial cells (Austin and Bergeron, 1995; Frank and Koffi, 1990; ICMS, 1980).

Washing whole melon with water before fresh-cut preparation did not cause significant ($p>0.05$) reductions in the numbers of native microorganisms on either rinds or their fresh-cut pieces compared to the fresh-cut pieces from the unwashed melons. Washing whole melon surfaces with 2.5% and 5% H_2O_2 caused a significant ($p<0.05$) reduction in the populations of indigenous microflora for both melons (Table 1). Populations of aerobes for the fresh-cut pieces prepared from treated melons were lower than the fresh-cut pieces from untreated melons. Aerobic mesophilic bacteria determined in fresh-cut pieces prepared from treated honeydew was <10 CFU/g and a 1.3 log CFU/g (5% H_2O_2) and 1.72 (2.5% H_2O_2) in fresh-cut pieces from treated cantaloupes. The populations of mesophilic aerobes reported in this study as well as the ineffectiveness of water washes to remove native bacteria from melon rinds are in agreement with previous reports (Ayhan et al., 1998; Ukuku et al., 2001). The results of a previous study designed to determine the shelf life of minimally processed honeydew and cantaloupe melon, kiwifruit, papaya and pineapple stored at 4 °C indicated that both the length of shelf life and type of spoilage were related to the type of fruit (O'Connor-Shaw et al., 1994). The authors suggested that the microflora of fruit pieces need to be studied to set appropriate criteria for quality assessment.

3.2. Effect of treatments on *Salmonella* spp.

The population of *Salmonella* spp. recovered from the surfaces of inoculated whole melon is shown in Table 2. Washing whole melons with water did not

Table 1

Aerobic plate counts for melon rind and fresh-cut pieces prepared from melons washed with water, or hydrogen peroxide treatments

Treatment	Colony forming unit (\log_{10} CFU)			
	Honeydew		Cantaloupe	
	Rind (CFU/cm ²)	Fresh-cut (CFU/g)	Rind (CFU/cm ²)	Fresh-cut (CFU/g)
Control	3.53 \pm 0.12	2.13 \pm 0.04	6.48 \pm 0.14	3.50 \pm 0.10
Water washed	3.38 \pm 0.16	2.05 \pm 0.04	6.09 \pm 0.10	3.32 \pm 0.12
H ₂ O ₂ (2.5%)	1.60 \pm 0.12*	<10 CFU/g	2.98 \pm 0.19*	1.72 \pm 0.13
H ₂ O ₂ (5%)	1.10 \pm 0.02*	<10 CFU/g	2.49 \pm 0.09*	1.32 \pm 0.03

Values are mean \pm standard deviation of three experiments with duplicate determinations.

*Indicate significant difference at ($p<0.05$).

Table 2

Population of *Salmonella* spp. on cantaloupe rind and the numbers recovered from fresh-cut pieces before or after washing treatments and fresh-cut preparation

Melon	Treatment	<i>Salmonella</i> population ^a			
		Log CFU/cm ² whole melon	Log reduction	Log CFU/g fresh-cut pieces	Log reduction
Cantaloupe	control	4.41 ± 0.12	—	2.12 ± 0.14	—
	water	4.28 ± 0.16	0.13	2.06 ± 0.14	0.06
	H ₂ O ₂ (2.5%)	1.89 ± 0.04	2.56	0.39 ± 0.09	1.73
	H ₂ O ₂ (5%)	2.12 ± 0.12	2.29	0.26 ± 0.09	1.86
Honeydew	control	3.13 ± 0.14	—	1.32 ± 0.13	—
	water	2.67 ± 0.16	0.51	1.25 ± 0.10	0.07
	H ₂ O ₂ (2.5 %)	ND	~ 3.00	ND	~ 1.32
	H ₂ O ₂ (5%)	ND	~ 3.00	ND	~ 1.32

(—) means sample was negative for the pathogen even after enrichment procedures. ND=pathogen was not determined from the sample after treatments.

^a Values are mean ± standard deviation of duplicate determinations from three trial experiments.

significantly ($p>0.05$) reduce the population of *Salmonella* compared to the controls or the fresh-cuts pieces. Washing the inoculated cantaloupe with 2.5% and 5% hydrogen peroxide for 5 min caused a significant reduction of *Salmonella*, but population reductions between the two treatments was not significant. Both concentrations caused approximately 3.0 log CFU/cm² reduction of *Salmonella* on honeydew melon. The population of *Salmonella* transferred from the untreated melons to the flesh during cutting averaged 2 log CFU/g on cantaloupe and a 1.3 log CFU/g for honeydew fresh-cut pieces. Fresh-cut

pieces prepared from treated honeydew melons were negative for the pathogen, while cantaloupe fresh-cut pieces were positive (Table 2).

3.3. Effect of storage temperature on microbial safety of fresh-cut pieces

The growth of aerobic mesophiles on minimally processed fresh-cut honeydew melons prepared from treated and untreated whole melon during storage is shown in Fig. 1. Growth was evident by day 6 in samples stored at 5 °C, and by day 15, the number

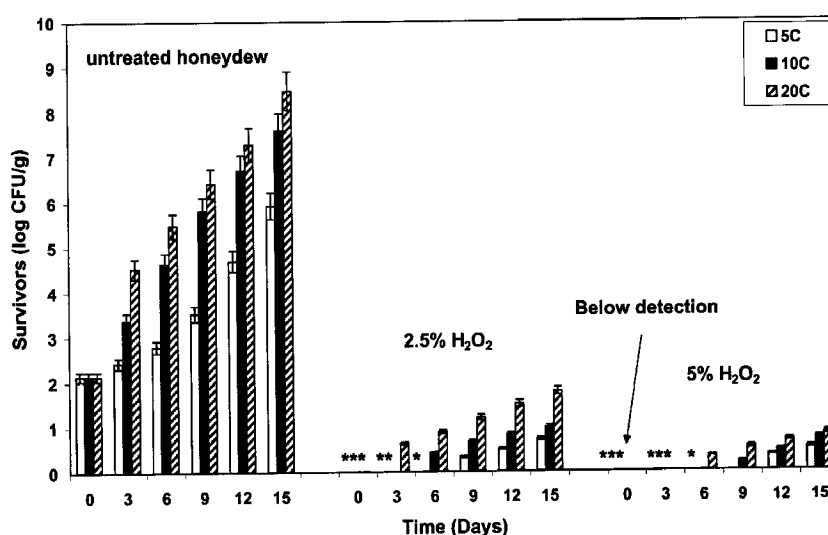


Fig. 1. Survival of aerobic mesophiles on fresh-cut melon prepared from treated and untreated honeydew melon with storage at 5, 10 and 20 °C. Values represent mean ± S.E. of values from three separate experiments. *Below level of detection.

increased in honeydew fresh-cut pieces by 3 log CFU/g. Fresh-cut melon pieces from treated honeydew contained lower populations of mesophilic aerobes. Growth of aerobes on fresh-cut pieces increased by approximately 3.0 log CFU/g during storage at 10 °C and 4.5 log CFU/g at 20 °C, respectively. Similar results on growth of aerobic mesophilic bacteria on fresh-cut cantaloupes during storage are shown in Fig. 2. Growth was evident by day 6 in samples stored at 5 °C, and by day 15, the number increased by 2 log. Fresh-cut pieces from treated cantaloupe pieces contained lower populations of mesophilic aerobes than the untreated. Growth of aerobes on fresh-cut pieces from treated whole cantaloupes (2.5 and 5%) increased by approximately 1 and 2 log CFU/g during storage at 5 °C, respectively.

Salmonella spp. recovered from the untreated fresh-cut pieces did not grow at 5 °C but increased in population at 10 and 20 °C storage (Fig. 3). *Salmonella* was not recovered on fresh-cut pieces washed with 1% hydrogen peroxide until day 6 at 20 °C and day 12 at 10 °C storage. The population in fresh-cut pieces (honeydew and cantaloupes) washed with 1% hydrogen peroxide was below the detection at 5 °C storage for 15 days. The level of *Salmonella* on fresh-cut pieces was approximately 0.5 and 1.5 log

CFU/g, after 15 days of storage at 10 and 20 °C, respectively.

Tamplin (1997) suggested that attention should be directed to cleaning the melons at the time of cutting, using clean and sanitized utensils and surfaces to minimize contamination of the edible portion and immediately consuming or holding cut melon pieces at cold temperatures. Washing of whole melon surfaces with water did not significantly reduce the populations of native bacteria or the *Salmonella* spp. All melon-related food-borne outbreaks noted so far involved melons that were pre-cut and held at unknown temperatures for some period of time at restaurants and food stores prior to being purchased and consumed. Washing treatments applied in this study did not completely remove the inoculated human pathogens on the melon surfaces. Our results are similar to previous studies that reported incomplete removal or inactivation of bacteria on fresh produce treated with chlorine (Beuchat, 1995; Brackett, 1992; Ukuku et al., 2001). Microorganisms embedded in plant tissues will be protected from chemicals such as chlorine that have little penetrating power during minimal processing of fruits and vegetables (Seo and Frank, 1999). Subsequent transfer of such protected microorganisms including bacterial pathogens to the internal tissue

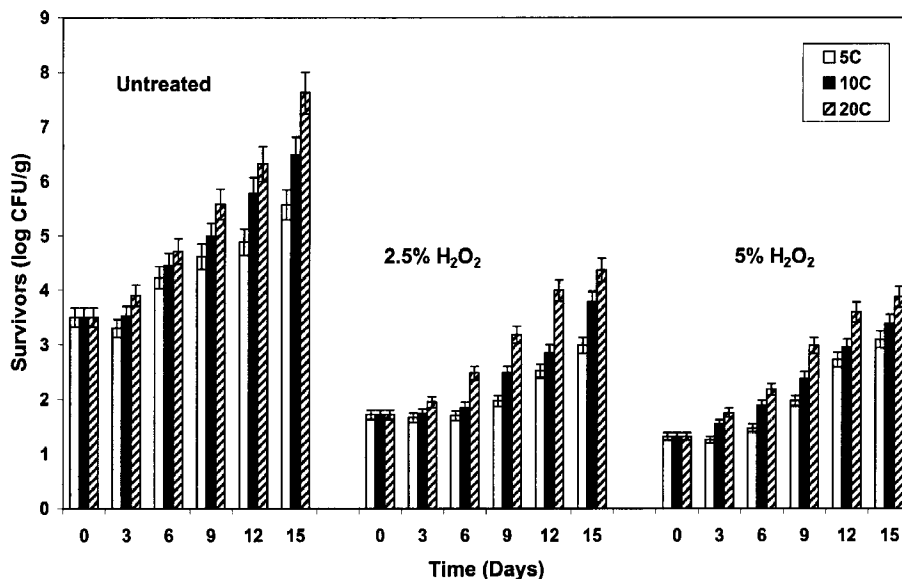


Fig. 2. Survival of aerobic mesophiles on fresh-cut melon prepared from treated and untreated cantaloupe melon with storage at 5, 10 and 20 °C. Values represent mean \pm S.E. of values from three separate experiments.

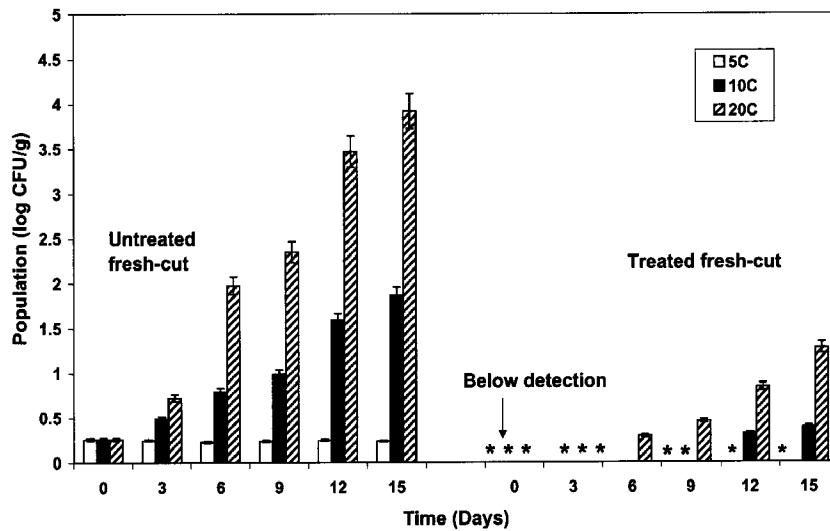


Fig. 3. Survival of *Salmonella* spp. population of contaminated fresh-cut cantaloupe pieces washed with 1% hydrogen peroxide with storage at 5, 10 and 20 °C. Values represent mean \pm S.E. of values from three separate experiments. *Below level of detection.

during cutting has been reported in studies using cantaloupe (Ukuku and Sapers, 2001) or tomato (Lin and Wei, 1997). Golden et al. (1993) reported growth of *Salmonella* spp. directly inoculated onto fresh-cut cantaloupe, watermelon and honeydew melons during storage at 23 °C. Ukuku and Sapers (2001) reported similar results on growth of *Salmonella* Stanley on fresh-cut cantaloupe during storage at

8 and 20 °C. Other investigators (Del Rosario and Beuchat, 1995; Escartin et al., 1989) have reported that interior watermelon tissues support the growth of *Salmonella* spp. The inner flesh of melons is composed mainly of parenchyma cells (Grigorieva et al., 1965) containing sugars, organic acids and other substances that may be released upon plant cell injury and support microbial growth.

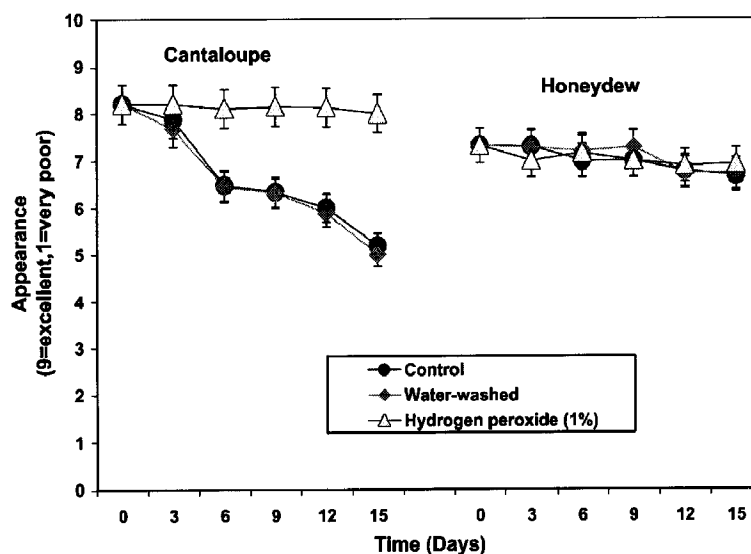


Fig. 4. Appearance rating for fresh-cut pieces from treated and untreated whole melons during storage at 5 °C. Values represent mean \pm S.E. of values from three separate experiments.

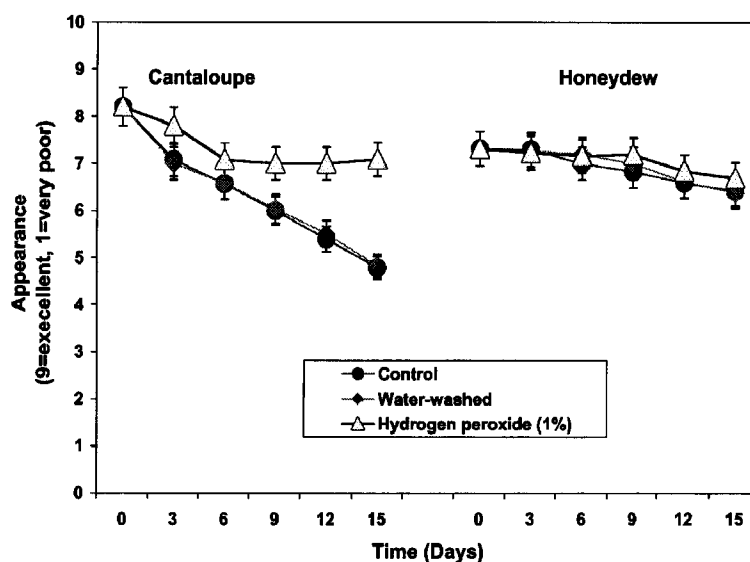


Fig. 5. Appearance rating for fresh-cut pieces from treated and untreated whole melons during storage at 10 °C. Values represent mean \pm S.E. of values from three separate experiments.

3.4. Effect of treatment on appearance and overall acceptability of fresh-cut melon

Sensory evaluation ratings for changes in appearance and overall acceptability for treated or untreated fresh-cut melon during storage at 5 °C is shown in Figs. 4–6. Appearance ratings for treated fresh-cut

cantaloupe pieces were significantly ($p < 0.05$) different from the control after 6 days of storage, and no significant ($p > 0.05$) differences in appearance for honeydew fresh-cut pieces (Fig. 4) was observed during storage at 5 °C. Similar results were obtained in fresh-cut pieces stored at 10 °C where appearance ratings for treated fresh-cut cantaloupe pieces were

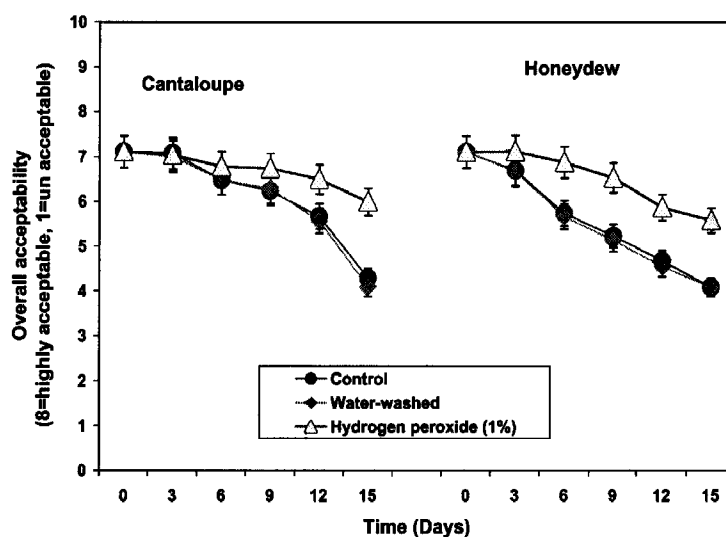


Fig. 6. Overall acceptability of fresh-cut melons washed with 1% hydrogen peroxide with storage at 5 °C. Values represent mean \pm S.E. of values from three separate experiments.

significantly ($p < 0.05$) different from the control after 12 days of storage, and again, no significant ($p > 0.05$) differences in appearance for honeydew fresh-cut pieces at this abusive temperature was observed (Fig. 5). The overall acceptability ratings for fresh-cut pieces from treated and untreated melons stored at 5 °C were not significantly different ($p > 0.05$) until days 12 for cantaloupe and 6 for honeydew pieces (Fig. 6). The overall acceptability rating for all fresh-cut pieces stored at 5 °C declined during storage.

The visual symptoms of deterioration of fresh-cut produce are flaccidity due to loss of water, changes in color resulting from oxidative browning at the cut surfaces and microbial contamination (King and Bolin, 1989; Varoquaux and Wiley, 1994; Brecht, 1995). In our study, washing inoculated whole melon in hydrogen peroxide before fresh-cut preparations had a positive effect on the acceptability of the fresh-cut melon. The results of this study suggests that up to 5% hydrogen peroxide can be used to reduce numbers of microbes including *Salmonella* spp. on whole melon surfaces and also may be used to delay growth of transferred microflora or *Salmonella*, thus extending the shelf life of fresh-cut melon. The use of hydrogen peroxide for this application on fresh-cut pieces is dependent on regulatory approval. Although the hydrogen peroxide treatment cannot be relied upon to completely sanitize whole cantaloupe or honeydew melons, such treatments will reduce the likelihood of contaminated melons reaching the consumer. In our study, the washing of fresh-cut pieces with 1% hydrogen peroxide had a positive effect on the acceptability of the fresh-cut melon presumably by inhibiting microbial growth, resulting in a longer refrigerated shelf life.

In conclusion, cantaloupe rinds harbor higher populations of native microflora than honeydew melon. Fresh-cut pieces prepared from untreated or water-washed inoculated cantaloupe melons underwent rapid quality changes in appearance, overall acceptability and microbial quality when compared with pieces prepared from treated honeydew melon. Hydrogen peroxide treatments before fresh-cut preparation significantly reduced transfer of native microflora and the inoculated *Salmonella* from the melon rind to the fresh-cut pieces. However, *Salmonella* spp. transferred to fresh-cut pieces during cutting survived but did not grow at 5 °C during storage for 15 days.

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